The Rotation Period of Saturn in 1903. By W. F. Denning.

The extensive disturbance observed on Saturn in 1903 offered an excellent opportunity for determining the rotation period of the north-temperate region of the planet. No doubt, however, the rate of the spots merely represented that of an atmospheric current, not nearly conformable with the motion of the globe.

To ascertain the rotation period reliably and within small limits of error it is by no means necessary to depend upon the transit times of spots derived by micrometric measurement. The method of eye estimation may not be quite so exact, but, as in the case of *Jupiter's* markings, it is capable of furnishing excellent results. There are certainly more important factors affecting such investigations than the manner of taking transits. The question of *identification* is a serious one. The mis-identification of planetary features has proved a fruitful source of large errors, and is scarcely avoidable unless observations are obtained at short intervals and a fairly numerous list of transits accumulated.

Large irregular markings, light and dark, were pretty abundant in the northern hemisphere of *Saturn* during the past year, and these underwent certain variations in aspect. The form, size, and brilliancy of the luminous spots appeared notably inconstant, and there were changes in the rate of motion. Several of the objects alluded to were compound, consisting of two or three parts wholly or partly divided by dusky masses or wisps similarly to those sometimes seen crossing the bright equatorial region of *Jupiter*. To follow the same individual marks on *Saturn*, and safely single them out one from another after various intervals, formed the most critical and delicate work in the recent telescopic study of the planet. As a test of the correctness of my own identifications I have collected together all the observed transits of spots I could find by various observers, and the comparisons made have, I hope, been the means of eliminating serious mistakes. I here append the transit times from observations secured between June 23 and September 22 of Barnard's spot, and of two smaller spots following it marked B, C, and D respectively. The times are compared with an adopted, uncorrected rate of $10^h\ 38^m$ and the residuals given.

Observed Transit Times of Barnard's White Spot on Saturn and of two other White Spots following it. 1903, *June* 23–*September* 22.

Observer.	Date. 1903.	Transit G.M.T. h m	Computed Period $10^h\ 38^m$. h m	Residual O−C. h m	Spot.	Notes.
Barnard ...	June 23	21 42	21 42	± 0	B	b., e., o.
Barnard ...	24	18 58	18 58	± 0	B	b., e., o.
Hartwig ...	26	13 36	13 30	+ 6	B	
Messow and Mainka	26	13 38	13 30	+ 8	B	

Observer.		Date. 1903.	Transit G.M.T. h m	Computed Period $10^h\ 38^m$. h m	Residual O−C. h m	Spot.	Notes.
Sola ...	...	June 26	13 19	13 30	− 11	B	d.
Hough	...	27	21 18·7	21 24	− 5·3	B	m.m.
Wilson	...	July 1	21 18	21 6	+ 12	B	b., e.
Graff	...	4	13 19	12 54	+ 25	B or C?	
Hough	...	6	18 49·4	18 4	+ 45·4	C	m.m.
Sola...	...	8	12 40	12 36	+ 4	B	
Sola...	...	9	10 0	9 52	+ 8	B	
Sola...	...	11	14 45	15 2	− 17	B	
Fauth	...	11	15 10	15 2	+ 8	B	
Brenner	...	12	12 18	12 18	± 0	B	e., m.m.
D. ...	...	12	12 50	12 18	+ 32	C	
Phillips	...	12	12 30	12 18	+ 12	B	
Kibbler	...	12	12 30	12 18	+ 12	B	
Hough	...	13	20 15·3	20 12	+ 3·3	B	m.m.
Barnard	...	13	20 11	20 12	− 1	B	b., e., s. spot f.
Barnard	...	14	17 26	17 28	− 2	B	s. spot f.
D. ...	...	16	11 52	12 0	− 8	B	v. b., l., e.
Brenner	...	16	12 0	12 0	± 0	B	m.m.
Brenner	...	17	9 16	9 16	± 0	B	m.m.
Hough	...	18	17 39·7	17 10	+ 29·7	C	m.m.
Sola...	...	20	11 32	11 42	− 10	B	
Sola...	...	21	9 45	8 58	+ 47	C	
Burnham	...	22	18 6	16 52	+ 1 14	D	
Sola...	...	24	11 25	11 24	+ 1	B	
D. ...	...	24	11 17	11 24	− 7	B	l. b.
Kibbler	...	24	11 30	11 24	+ 6	B	d.
Williams	...	24	11 34	11 24	+ 10	B	d.
D. ...	...	24	12 40	11 24	+ 1 16	B	s. o.
Sola...	...	28	11 15	11 6	+ 9	B	
Burnham	...	29	19 20·9	19 0	+ 20·9	B	or C? m.m.
Burnham	...	30	17 26·5	16 16	+ 1 10·5	D	m.m.
Williams	...	31	13 21	13 32	− 11	B	o.
Barnard	...	Aug. 2	19 57	18 42	+ 1 15	D	s., b., o., e
Phillips	...	4	13 5	13 14	− 9	B	
D. ...	...	5	10 20 / 10 31	10 30	− 10 / + 1	B	b., e.
Brenner	...	5	10 30	10 30	± 0	B	m.m.
Phillips	...	5	10 40	10 30	+ 10	B	

Observer.		Date. 1903.	Transit G.M.T. h m	Computed Period $10^h\ 38^m$. h m	Residual O−C. h m	Spot.	Notes.
D. ...	...	Aug. 5	11 35	10 30	+1 5	D	
D. ...	...	12	12 24	12 38	− 14	B	b., o.
Williams	...	13	10 14	9 54	+ 20	B	s.
Brenner	...	17	9 36	9 36	± 0	B	
Burnham	...	19	15 31·2	14 46	+ 45·2	C	f.
Brenner	...	21	9 18	9 18	± 0	B	s., m.m.
D. ...	...	21	10 9	9 18	+ 51	C	r. s., o.
D. ...	...	25	9 12	9 0	+ 12	B	
D. ...	...	25	10 18	9 0	+1 18	D	
D. ...	...	29	8 37	8 42	− 5	B	b., o.
D. ...	...	29	10 3	8 42	+1 21	D	
D. ...	...	Sept. 2	8 28	8 24	+ 4	B	
D. ...	...	2	9 36	8 24	+1 12	D	
D. ...	...	5	10 44	10 50	− 6	B	o.
Williams	...	5	11 5	10 50	+ 15	B	s.
D. ...	...	6	7 50	8 6	− 16	B	f.
D. ...	...	6	8 40	8 6	+ 34	C	
Williams	...	9	10 41	10 32	+ 9	B	b.
Williams	...	13	10 24	10 14	+ 10	B	d.
D. ...	...	14	8 8	7 30	+ 38	C	
Williams	...	17	10 7	9 56	+ 11	B	s., b., o.
D. ...	...	17	10 9	9 56	+ 13	B	o.
D. ...	...	18	7 25	7 12	+ 13	B	
D. ...	...	22	6 49	6 54	− 5	B	o.
D. ...	...	22	8 12	6 54	+1 18	D	

In first column transits by D. = Denning.

In last column: b., bright; f., faint; d., double; e., extended; l., large; s., small; o., obvious; m.m., micrometric measure; v., very; r., rather; p., preceding; f., following.

The discussion of a considerable number of transits of bright spots recorded here and elsewhere show that the corrected rotation period was as nearly as possible

$$10^h\ 38^m\ 3^s$$

between the latter part of June and middle of September. Then a marked acceleration apparently occurred, and from the observations made at Bristol, July to December, of fifteen bright and dark spots the mean rate of rotation was about

$$10^h\ 37^m\ 56^s.$$

I shall be glad if Professor Hough will look into the foregoing table of transits, for I am bound to conclude that in his interesting paper in *Monthly Notices* for 1903 December, p. 122, he has incorrectly identified the very few (though doubtless accurate) observations taken by himself at the Dearborn Observatory and by Professor Burnham at the Yerkes Observatory. The rotation periods he has deduced are therefore too great. The observation of August 19, $15^h\ 31^m{\cdot}2$ G.M.T., was certainly not of Barnard's spot at all, but of a smaller object further south, and following it about three-quarters of an hour. Professor Barnard (*Astronomical Journal*, No. 547, p. 180) specially alludes to a smaller spot, following on July 13 and 14, the principal one which he was the first to discover. The same object also came under observation on several occasions at Bristol. Professor Hough, in his paper alluded to, also identifies spots seen on July 6, 22, and 30 (period $10^h\ 38^m\ 30^s{\cdot}5$), but the first of these was different, and very probably the same as that of August 19, marked C in the foregoing table. The transits of July 22 and 30 undoubtedly referred to the same marking (marked D in the table), and this object was well observed by Barnard on August 2, and many times at Bristol in July and subsequent months, following Barnard's spot about an hour and a quarter.

I entirely differ from Professor Hough in his depreciation of eye-estimated transits of markings on *Jupiter* and *Saturn*. Professor Hall, in his valuable and accurate observations of the white equatorial spot which he discovered on *Saturn* in 1876 December, relied upon eye estimations, and concluded the probable error of determining the time when the spot was at the centre of the disc to be ± 3 min. on a good night and ± 5 min. on a bad one. Professor Barnard's two pairs of eye-estimated transits of his recent spot clearly prove two things—viz. that its period was just about $10^h\ 38^m$, and that the four observations were very accurate and comparable with the best instrumental measures :—

Date.	Transit Time.	Rate of $10^h\ 38^m$	Difference.
	h m	h m	min.
June 23	21 42	21 42	±0
24	18 58	18 58	±0
July 13	20 11	20 12	−1
14	17 26	17 28	−2

In the table giving the combined results of observers the residuals are certainly rather large in some cases. This is due to several causes—viz. the bad definition often prevailing, the changing aspects of the spots, and their duple or triple appearance in several instances. And it is quite possible that the individual markings, like the equatorial spots on *Jupiter*, presented irregularities of motion, causing them to oscillate to and fro about their mean positions.

It will be noticed that Herr Brenner's six observations of Barnard's spot agree to the very minute with the uncorrected rotation period of $10^h\ 38^m$. I cannot explain this singular circumstance.

With reference to the transits of minor spots obtained by Professors Hough and Burnham, I may add that I made eight observations of each of Burnham's spots of July 23, $17^h\ 28^m$ and $17^h\ 57^m$ G.M.T. Hough's transit of August 20, $15^h\ 32^m{\cdot}3$ G.M.T. seems to be of the former marking of the pair. It followed Barnard's spot about $3^h\ 24^m = 115°$. I have twelve observations of Burnham's spot of August 9, $17^h\ 32^m{\cdot}6$ G.M.T., which preceded Barnard's spot about $3^h\ 10^m = 107°$.

Observations of *Saturn* were made here on seventy-eight nights between July 1 and December 11. The last good observation of Barnard's spot was on November 24, $4^h\ 17^m$, when it preceded the zero meridian (rate $10^h\ 38^m$ uncorrected) 27 minutes. The spot C in the table I appear to have lost after September, but D I retained in view until December 10, when it was in transit at $4^h\ 30^m$, and followed the z.m. 52 minutes.

This z.m. requires to be corrected chiefly for differences in the longitude and distance of *Saturn*. Between the end of June and middle of September (the period comprised in the table) there would be a *plus* correction of more than 2 seconds per rotation for the relative displacement in longitude. Between the end of June and beginning of December there was a slight *minus* correction of about 1 second, the far greater distance of *Saturn* more than compensating for the variation in longitude.

I hope to place before a later meeting of the Society some further details of my observational results, with a determination of the mean rotation period.

Bishopston, Bristol: 1904 *January* 4.

Ephemeris for Physical Observations of

Greenwich Noon. 1904.		P.	L−O.	B.	Apparent Diameter. Equat. Diam.	Excess over Polar.	Defect of Illum.	d.	Q.
		°	°	°	″	″	″	°	°
May	1	335·580	239·076	+2·442	34·22	2·20	0·07	5·12	245·01
	5	335·693	239·986	2·474	34·39	2·21	0·08	5·67	245·33
	9	335·808	240·883	2·506	34·57	2·22	0·10	6·20	245·63
	13	335·927	241·768	2·538	34·77	2·23	0·12	6·71	245·91
	17	336·048	242·635	2·569	34·99	2·25	0·14	7·21	246·18
	21	336·172	243·485	2·600	35·23	2·26	0·16	7·70	246·43
	25	336·300	244·317	2·630	35·48	2·28	0·18	8·16	246·66
	29	336·428	245·128	2·661	35·75	2·30	0·20	8·61	246·88
June	2	336·558	245·918	2·692	36·05	2·32	0·22	9·03	247·10
	6	336·688	246·686	2·726	36·36	2·34	0·24	9·43	247·31
	10	336·817	247·429	2·758	36·69	2·36	0·26	9·81	247·52
	14	336·945	248·145	2·789	37·04	2·38	0·28	10·16	247·71
	18	337·072	248·834	2·819	37·41	2·41	0·31	10·48	247·90
	22	337·196	249·492	2·845	37·80	2·43	0·33	10·77	248·06
	26	337·318	250·121	2·870	38·20	2·46	0·35	11·03	248·22
	30	337·436	250·716	2·895	38·63	2·49	0·37	11·26	248·37
July	4	337·548	251·277	2·920	39·07	2·52	0·39	11·45	248·51
	8	337·655	251·799	2·947	39·53	2·55	0·41	11·61	248·67
	12	337·756	252·284	2·974	40·00	2·58	0·42	11·73	248·84
	16	337·849	252·728	2·999	40·50	2·61	0·43	11·80	249·00
	20	337·936	253·129	3·023	41·01	2·64	0·44	11·84	249·16
	24	338·014	253·487	3·046	41·52	2·67	0·44	11·83	249·32
	28	338·083	253·800	3·069	42·05	2·71	0·45	11·78	249·48
Aug.	1	338·142	254·066	3·091	42·59	2·74	0·44	11·67	249·63
	5	338·192	254·283	3·112	43·15	2·78	0·44	11·52	249·78
	9	338·229	254·449	3·133	43·70	2·81	0·43	11·33	249·91
	13	338·255	254·563	3·152	44·26	2·85	0·41	11·07	250·04
	17	338·270	254·625	3·170	44·83	2·88	0·39	10·76	250·17
	21	338·274	254·633	3·186	45·39	2·92	0·37	10·41	250·30
	25	338·265	254·589	3·201	45·93	2·95	0·35	10·00	250·43
	29	338·244	254·493	3·215	46·47	2·99	0·32	9·54	250·58
Sept.	2	338·212	254·342	3·226	47·00	3·02	0·29	9·02	250·74
	6	338·169	254·141	3·236	47·52	3·06	0·26	8·46	250·91
	10	338·110	253·889	3·244	47·99	3·09	0·23	7·84	251·10
	14	338·041	253·588	3·249	48·43	3·12	0·20	7·17	251·35